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# REPORT

Physical &  
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Serials

OF

## THE SUPERINTENDENT

OF THE

# U. S. NAVAL OBSERVATORY

FOR THE

## YEAR ENDING 1891 JUNE 30

635-  
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WASHINGTON

GOVERNMENT PRINTING OFFICE

1891



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*ANNUAL REPORT OF THE SUPERINTENDENT OF THE NAVAL OBSERVATORY.*

U. S. NAVAL OBSERVATORY,  
*Washington, September 21, 1891.*

SIR: In compliance with the order of the Bureau No. 3787, dated September 14, 1891, I have the honor to submit a report of the operations of the Observatory during the year ending June 30, 1891.

THE 26-INCH EQUATORIAL.

The observer on this instrument, Prof. Asaph Hall, U. S. Navy, has been engaged in completing his observations of double stars and in reducing and collecting these observations into a catalogue. This work is nearly accomplished. It is intended to make a new investigation of the periodical errors of the screw of the micrometer, and also to make some observations for the flexure and position of the instrument. This will close the work with this instrument before its removal to the new site.

For the reason stated above but few observations of satellites and other objects, except double stars, have been made. Some of these stars are close and difficult objects, which can be observed only on fine nights, and hence they have required a good deal of time.

THE TRANSIT CIRCLE.

This instrument, in charge of Prof. J. R. Eastman, U. S. Navy, was employed in observations of the sun, moon and planets, and such stars as were necessary for clock and instrument corrections. Observations of the list of stars for the Coast and Geodetic Survey were completed in 1890. Since July 1, 1890, 1,875 observations have been made with the transit circle. Of these 92 were of the sun, 53 of the moon, 48 of Mercury, 69 of Venus, 5 of Jupiter, and 5 of Saturn. The assistants on the transit circle were: Assistant Astronomers A. N. Skinner and Asaph Hall, jr.; Computers Charles S. McCoy and George A. Hill. The limited number of observers has prevented any work on the zone  $-14^{\circ}$  to  $-18^{\circ}$ .

The transit-circle work for 1887 is in type and that for 1888 will soon be ready for the printer. In addition to their work on astronomical reductions, the computers have reduced and prepared for publication, under Prof. Eastman's direction, the meteorological observations and results for the years 1883, 1884, 1885, 1886 and 1887. This meteorological work will form Appendix 3 to the volume for 1887. Of the reductions of the transit-circle work for 1889 more than half has been completed.

THE 9.6-INCH EQUATORIAL.

This instrument, in charge of Prof. Edgar Frisby, U. S. Navy, has been used in the observations of comets, asteroids, occultations of stars by the moon, and some miscellaneous observations of stars whose position needed identification. Observations of five different comets and of seven asteroids were made as often as possible; observations were also made of seven occultations of stars and of the transit of Mercury. The

observations are all reduced to date and most of the results have already been communicated to astronomical journals.

Two nights in each week have been set apart for the accommodation of visitors.

#### THE TRANSIT OF MERCURY.

The transit of Mercury over the sun's disk, which occurred on May 9, 1891, was observed with the 9.6-inch equatorial by Prof. Frisby. The transit was only partial in the United States. On the Pacific coast the sun was two or three hours high at the time of the first and second contacts; it had set in most places on the Atlantic coast before the first contact, and in Washington it was only about ten minutes high. The afternoon of the day was quite cloudy, but just before the time of transit the clouds broke away and the first and second contacts were quite successfully observed; but, on account of the unfavorable circumstances and the sun's low altitude, the observations can not be very valuable, although the first indentation on the sun's limb was recorded on the chronograph.

In answer to a circular issued by the Observatory, requesting different astronomers throughout the country to observe the transit, responses were received from about twenty-five observers. The discussion of all these reports will doubtless increase our knowledge of the motion of this planet.

#### TRANSITS OF VENUS.

The reduction and discussion of the photographs of the transit of Venus, which occurred in December, 1882, is finished in the sense that results have been attained for the solar parallax and certain elements of the orbit of Venus, which are final, except in so far as they may be affected by possible small changes in the adopted longitudes of the various stations. Nevertheless some occultations of stars by the moon, telegraphic determinations of differences of longitude, tidal observations, and pendulum experiments still remain to be reduced, and as no funds are available for that purpose the work proceeds very slowly.

By the resolutions of April 10 and June 22, 1879, Congress provided for printing the observations of the transit which occurred in December, 1874, and under these resolutions Senate Ex. Doc. No. 31, Forty-sixth Congress, First session, containing 157 quarto pages, has been published, and 564 additional pages are now in type but have not yet been printed. Hitherto no provision has been made for printing the observations of the transit of December, 1882, but it is hoped that this may soon be done, because the work has now arrived at a stage where these observations should be introduced in order to show how a single result has been derived from the two transits. The meager statement of the results attained has been made in the report of the Superintendent of the Observatory for the year 1889, but until the observations are published in the detailed form adopted by other great nations the benefits accruing from the money already expended can not be fully realized.

#### SOLAR ECLIPSE OF 1893 APRIL 15.

On April 15, 1893, a total solar eclipse occurs under circumstances so favorable that its observation is extremely desirable. The central line of the shadow sweeps across South America, the Atlantic Ocean, and

the northwestern part of Africa, and the duration of totality is 4<sup>m</sup> 42<sup>s</sup> near Ceara, Brazil, and 4<sup>m</sup> 10<sup>s</sup> near Bathurst, Senegambia. Many of the most important questions relating to the constitution of the sun can be studied only during total eclipses, and, as the whole time available for that purpose is only about three hours in a century, the necessity for utilizing every available eclipse is evident if we are ever to comprehend that wonderful orb upon which the very existence of the human race depends. It is hoped that means may be provided for sending at least one party to Ceara, and, if possible, another to Bathurst.

#### THE MERIDIAN TRANSIT INSTRUMENT.

The transit instrument has been constantly in use during the year for the daily observations to determine the errors of the standard-mean-time and other clocks for use in the transmission of standard time, and for the comparison of the chronometers. Observations have been taken with this instrument on every favorable night. The clocks continue to perform well, their rates seeming to follow the barometric movement more than any thermometric or hygrometric change.

A portable transit has been mounted and adjusted for use during the transfer and mounting of the large instrument at the new observatory.

The meridian transit instrument was in charge of Lieut. B. W. Hodges, U. S. Navy, until September 1, 1890, when he was relieved by Ensign Thomas Snowden, U. S. Navy. Ensign Hugh Rodman, U. S. Navy, assisted in the work with this instrument until relieved by Ensign H. H. Whittlesey, U. S. Navy.

#### CHRONOMETERS AND TIME SERVICE.

During the year 60 chronometers were issued, 37 turned in, 18 purchased, and 63 surveyed, of which 51 were sold and 12 retained for use in the Observatory.

Forty-six chronometers were repaired by the different firms and 20 are now undergoing repairs.

Of the chronometers owned by the government, 12 are in use at the Observatory, 53 are ready for issue, 17 await trial, 7 hack chronometers are ready for issue, 114 chronometers and 42 hacks are in use on naval vessels, 39 chronometers and 12 hacks are at the Mare Island observatory for issue to vessels, 17 chronometers and 20 hacks are in use on receiving ships, at shore stations, and for scientific purposes, 10 are held for survey, 17 are held for the Observatory museum, and 25 are awaiting repairs.

Besides the above instruments, there are 5 pocket chronometers, 23 watches, and 27 thermometers for issue, 2 watches requiring repairs; 8 watches and 2 thermometers are held for survey.

The Bureau of Equipment, having notified the several chronometer makers of the intention of the government to purchase a number of chronometers for the naval service, Messrs. T. S. & J. D. Negus submitted 16, John Bliss & Co. 13, H. H. Heinrich 8, and William Bond & Son 4 chronometers for competitive trial, of which number 18 were purchased. The trial of these chronometers began January 1, 1891, and was completed June 9, 1891. The results of the trial are appended in Table A.



Besides this trial, two trials of repaired chronometers were held during the year, lasting three months each, the results of which are appended in Tables B and C. These trials were conducted in the same manner as those of preceding years, which have been described at length.

The time service has been satisfactory, the usual signals having been sent over the connecting wires, the same number of time-balls dropped, the Government clocks corrected, and the fire-alarm-circuit signals sent out, as formerly. This division of the Observatory, comprising the chronometers and the time service, was in charge of Lieut. Hiero Taylor, U. S. Navy, until May 1, when he was relieved by Ensign Thomas Snowden, U. S. Navy. Ensign H. P. Jones, U. S. Navy, and Ensign H. H. Whittlesey, U. S. Navy, have assisted in the chronometer work.

#### NAUTICAL INSTRUMENTS.

The instruments used in the navigation of ships have been carefully examined by Lieutenant-Commander Walton Goodwin, U. S. Navy, before acceptance, and distributed as directed by the Chief of the Bureau of Equipment.

A number of octants have been fitted with the telescope with large object-glass, for night observations. The binocular and spy glasses received during the year are of a quality superior to those formerly issued to the naval service.

A number of old chronometers, sextants, octants, and other instruments were condemned by survey as unserviceable, obsolete, and worn out, and were sold.

Two thousand three hundred and sixty permits were issued for a view of the heavens through the telescope.

#### MAGNETIC INSTRUMENTS.

The magnetic observations were under the charge of Ensign J. A. Hoogewerff, U. S. Navy. Ensign W. B. Hoggatt, U. S. Navy, was assistant until January 27, and Ensign R. E. Coontz, U. S. Navy, until June 30.

The self-recording magnetographs have been in operation continuously during the year, and the traces made by them developed, measured, and recorded. Experiments to determine the scale-values in terms of the force, and the temperature-corrections of the horizontal and vertical-force instruments, have been made as frequently as necessary throughout the year.

Observations of the absolute declination (variation of the compass) have been made twice a day during the year, between 9 and 10 a. m. and noon and 3:30 p. m., and the values of the base lines of the declination traces deduced from them.

Observations of the horizontal intensity of the earth's magnetic force have been made on four days of each month.

Two observations of the magnetic inclination (dip) have been made on each of the four days of each month on which the horizontal intensity was observed.

The actual number of the absolute observations is as follows: 503 observations of declination, 21 of horizontal intensity, and 84 of inclination.

The results of the absolute observations have been reduced and combined with the continuous photographic records, and the absolute declination, horizontal force, and vertical force of the earth's magnetism were found and tabulated for each hour of the year.

The reduced observations for 1888 and 1889 have been published, and those for 1890 are now in the hands of the printer.

Two seismoscopes and a seismograph have been kept in working order during the year.

A report by Ensign C. C. Marsh, U. S. Navy, on "Some of the Magnetic Observatories of Europe" has been prepared for publication and is now at the Printing Office.

A continuous graphic record of the variation of the compass at this observatory since March 29, 1891, has been furnished to the Hydrographic Office, and has been published by it on the Monthly Pilot Chart of the North Atlantic Ocean.

#### LIBRARY AND PUBLICATIONS.

The library, together with the distribution of the publications of the Observatory, has remained in charge of Assistant Astronomer H. M. Paul.

The contents of the library at the beginning and end of the fiscal year 1890-91, with the additions during the year, were as follows:

|                              | Volumes. | Pamphlets. | Total. |
|------------------------------|----------|------------|--------|
| Contents, 1890 June 30 ..... | 12,643   | 2,915      | 15,558 |
| Additions .....              | 559      | 146        | 705    |
| Contents, 1891 June 30 ..... | 13,202   | 3,061      | 16,263 |

Of the 705 additions, 391 were received in exchange and 314 by purchase.

About 350 volumes have been bound during the year, but this does not suffice for the growth of the library. The binding has fallen very far behind, on account of the frequent suspension of work upon requisitions, and it is now practically two years in arrears. Some of the books now at the bindery have been there already more than eight months. The only apparent remedy for these difficulties is in granting the Observatory its own fund for binding, and a considerable increase in the estimate for the library has been submitted for this purpose, which it is hoped may have the approval of the Bureau and the Department.

The following publications have been distributed to the regular exchange lists:

1. The annual report of the Superintendent for 1890.
2. The Washington Observations for the year 1885.
3. The Washington Observations for the year 1886.
4. 1885, Appendix 3.—The Solar Parallax and its Related Constants, by Prof. Wm. Harkness, U. S. Navy.
5. 1886, Appendix I.—Magnetic Observations, 1888-89, by Ensign J. A. Hoogewerff, U. S. Navy.

The annual volume for 1887 will shortly be ready for distribution, and that for 1888 is nearly ready for the printer.

## NEW NAVAL OBSERVATORY.

The new Naval Observatory buildings are not yet completed, and from present indications the removal from the old to the new Observatory will not be accomplished until July, 1892.

Very respectfully,

F. V. McNAIR,

*Captain U. S. Navy, Superintendent.*

The CHIEF OF THE BUREAU OF EQUIPMENT,

*Navy Department.*

TABLE A.—Record of competitive trial

[In temperature room January 1 to March 14; after that to May

| Relative number. | Time, 1891 .....               |    | Jan. 2 to Jan. 9. | Jan. 10 to Jan. 17. | Jan. 18 to Jan. 25. | Jan. 25 to Feb. 2. | Feb. 3 to Feb. 10. | Feb. 11 to Feb. 18. | Feb. 19 to Feb. 26. | Feb. 27 to Mar. 6. | Mar. 7 to Mar. 14. |        |
|------------------|--------------------------------|----|-------------------|---------------------|---------------------|--------------------|--------------------|---------------------|---------------------|--------------------|--------------------|--------|
|                  |                                |    |                   |                     |                     |                    |                    |                     |                     |                    |                    |        |
|                  | Temperature, Fahrenheit .....  |    | 45.04             | 54.95               | 70.03               | 85.09              | 90.04              | 85.01               | 69.95               | 55.03              | 45.30              |        |
|                  | Relative humidity, per cent... |    | 65.3              | 69.4                | 68.8                | 69.9               | 68.0               | 68.6                | 69.3                | 69.6               | 70.1               |        |
|                  | <i>Chronometer maker.</i>      |    | <i>No.</i>        | <i>s.</i>           | <i>s.</i>           | <i>s.</i>          | <i>s.</i>          | <i>s.</i>           | <i>s.</i>           | <i>s.</i>          | <i>s.</i>          |        |
| 1                | John Bliss & Co.....           | a. | 2827              | -1.226              | -1.324              | -1.086             | -1.646             | -1.909              | -1.617              | -1.150             | -1.243             | -1.660 |
| 2                | do .....                       | a. | 2860              | +0.596              | +0.069              | -0.371             | -0.289             | +0.199              | +0.097              | -0.114             | -0.029             | +0.269 |
| 3                | T. S. & J. D. Negus ...        | b. | 1774              | +0.524              | +0.926              | +0.771             | +0.854             | +1.127              | +0.811              | +0.386             | +0.329             | +0.876 |
| 4                | do .....                       | b. | 1783              | +2.060              | +2.176              | +2.093             | +1.676             | +2.199              | +1.704              | +2.207             | +2.150             | +1.840 |
| 5                | John Bliss & Co.....           | a. | 2843              | +0.346              | +0.319              | +0.521             | -0.569             | -0.806              | +0.633              | +0.636             | +0.757             | +0.769 |
| 6                | do .....                       | a. | 2858              | +1.381              | +0.104              | -0.228             | -0.569             | +1.056              | +0.490              | -0.150             | +0.007             | +0.840 |
| 7                | Wm. Bond & Son .....           | c. | 425               | -0.762              | -0.360              | +0.164             | +0.319             | +0.341              | +0.490              | +0.207             | -0.457             | -0.231 |
| 8                | T. S. & J. D. Negus ...        | d. | 1764              | +2.810              | +1.961              | +1.707             | +2.497             | +3.091              | +2.490              | +2.029             | +2.400             | +3.340 |
| 9                | John Bliss & Co.....           | a. | 2829              | +1.846              | +1.069              | +0.736             | -0.211             | -0.556              | +0.633              | +0.564             | +1.114             | +1.019 |
| 10               | do .....                       | a. | 2851              | +1.810              | +1.640              | +0.807             | +0.354             | +0.663              | +0.490              | +0.707             | +1.114             | +1.519 |
| 11               | do .....                       | a. | 2837              | -0.619              | -2.253              | -3.228             | -2.967             | -2.480              | -3.010              | -3.114             | -2.207             | -0.910 |
| 12               | H. H. Heinrich .....           | e. | 1007              | +1.953              | +0.461              | -0.050             | +0.926             | +1.199              | +0.704              | +0.064             | +0.471             | +1.519 |
| 13               | Wm. Bond & Son .....           | c. | 504               | -0.310              | +1.997              | +2.593             | +3.033             | +3.127              | +3.026              | +2.957             | +1.864             | +1.126 |
| 14               | T. S. & J. D. Negus ...        | b. | 1776              | +2.846              | +2.283              | +2.307             | +1.854             | +2.591              | +2.633              | +2.243             | +2.436             | +2.983 |
| 15               | John Bliss & Co.....           | a. | 2792              | -0.833              | -0.681              | +0.057             | +0.140             | +0.020              | -0.046              | +0.171             | -0.529             | -1.410 |
| 16               | T. S. & J. D. Negus ...        | b. | 1777              | -0.404              | -0.824              | -0.550             | -0.181             | -0.087              | -0.260              | -0.150             | -0.743             | -0.410 |
| 17               | do .....                       | d. | 1801              | +2.096              | +1.533              | +1.414             | +2.319             | +3.163              | +2.597              | +1.814             | +2.007             | +2.697 |
| 18               | do .....                       | b. | 1787              | -0.476              | +0.069              | +0.093             | +0.211             | +0.413              | -0.010              | -0.721             | -0.529             | -0.410 |
| 19               | do .....                       | b. | 1780              | -0.654              | -1.574              | -1.336             | -1.146             | -0.801              | -1.010              | -1.471             | -1.636             | -1.267 |
| 20               | H. H. Heinrich .....           | f. | 1001              | +0.131              | -0.467              | +0.271             | +1.104             | +1.270              | +1.383              | +0.421             | +0.186             | +0.307 |
| 21               | T. S. & J. D. Negus ...        | d. | 1802              | +1.453              | -0.140              | -0.764             | -0.467             | -0.051              | -0.689              | -1.079             | -0.171             | +1.161 |
| 22               | do .....                       | d. | 1765              | +2.024              | +0.604              | -0.229             | +0.783             | +1.306              | +0.954              | +0.029             | +0.686             | +2.019 |
| 23               | John Bliss & Co.....           | a. | 2850              | -1.203              | +0.069              | -0.621             | -0.967             | -0.587              | -1.189              | -0.364             | +0.614             | +1.054 |
| 24               | T. S. & J. D. Negus ...        | b. | 1782              | -3.417              | +2.604              | +2.093             | +1.997             | +1.949              | +2.847              | +2.386             | +2.686             | +3.411 |
| 25               | do .....                       | b. | 1784              | +1.596              | +2.176              | +2.807             | +2.854             | +3.484              | +3.347              | +3.457             | +2.721             | +2.697 |
| 26               | do .....                       | d. | 1718              | +1.667              | -0.247              | -0.336             | -0.997             | +1.663              | +1.204              | +0.171             | +0.686             | +2.126 |
| 27               | John Bliss & Co.....           | a. | 2855              | +2.167              | -0.890              | -0.121             | +1.069             | +1.984              | +1.633              | +0.921             | +0.900             | +2.054 |
| 28               | Wm. Bond & Son .....           | d. | 480               | -0.453              | -0.503              | +0.307             | +1.997             | +2.627              | +2.061              | +0.529             | +0.150             | +0.876 |
| 29               | H. H. Heinrich .....           | g. | 712               | -0.560              | -0.747              | +1.236             | +1.319             | +2.020              | +1.811              | +2.171             | +2.114             | +1.697 |
| 30               | John Bliss & Co.....           | a. | 2810              | +2.417              | +0.461              | +0.414             | +0.140             | +0.127              | -0.046              | +0.564             | +1.114             | +1.554 |
| 31               | H. H. Heinrich .....           | h. | 1005              | +0.810              | +0.461              | +0.664             | +0.568             | +0.163              | -0.260              | +0.600             | +0.686             | +1.197 |
| 32               | Wm. Bond & Son .....           | i. | 1009              | +1.524              | +1.461              | +2.664             | +2.854             | +2.377              | +2.454              | +2.886             | +2.257             | +2.019 |
| 33               | John Bliss & Co.....           | a. | 2852              | +2.453              | +1.926              | +0.771             | +1.176             | +1.984              | +1.454              | +1.100             | +2.400             | +3.269 |
| 34               | T. S. & J. D. Negus ...        | b. | 1772              | +0.810              | +0.319              | +0.236             | +0.854             | +1.306              | +1.490              | +1.636             | +1.650             | +2.126 |
| 35               | H. H. Heinrich .....           | e. | 1002              | +1.917              | +1.033              | -0.407             | -1.217             | -0.623              | -1.153              | -1.436             | -0.207             | +1.161 |
| 36               | T. S. & J. D. Negus ...        | d. | 1737              | +2.560              | +1.461              | +1.093             | +1.783             | +2.413              | +2.097              | +2.457             | +3.114             | +3.626 |
| 37               | H. H. Heinrich .....           | j. | 1003              | +1.667              | +1.890              | +1.271             | +1.604             | +1.913              | +1.169              | +0.386             | +0.436             | +3.019 |
| 38               | John Bliss & Co.....           | a. | 2828              | +0.953              | +1.033              | +0.879             | +0.211             | +0.949              | +1.097              | +2.136             | +2.114             | +1.447 |
| 39               | H. H. Heinrich .....           | k. | 1008              | -1.154              | -0.360              | -0.121             | +0.176             | +0.341              | +0.311              | +1.993             | -0.171             | -0.267 |
| 40               | T. S. & J. D. Negus ...        | b. | 1786              | +0.310              | -0.533              | +0.736             | +0.890             | +0.984              | +0.954              | +0.529             | +0.150             | -0.089 |
| 41               | H. H. Heinrich .....           | l. | 1004              | -1.047              | +0.783              | -0.050             | -1.360             | -2.873              | -3.153              | -1.614             | -0.850             | -0.660 |

NOTE.—The sign + signifies losing; - signifies gaining.

a Ordinary balance with Bliss corrector.

b Ordinary balance with Negus correction.

c Hartnup balance.

d Ordinary balance.

e Heinrich regulator, white steel spring.

f Heinrich compensating weights, white steel spring.

of chronometers, January to June, 1891.

23, in chronometer room; then in temperature room to June 9.]

| Mar. 14 to<br>Mar. 21. | Mar. 21 to<br>Mar. 28. | Mar. 28 to<br>Apr. 4. | Apr. 4 to<br>Apr. 11. | Apr. 11 to<br>Apr. 18. | Apr. 18 to<br>Apr. 25. | Apr. 25 to<br>May 2. | May 2 to<br>May 9. | May 9 to<br>May 16. | May 16 to<br>May 23. | Temperature of com-<br>pensation. | Temperature-constant. | First trial number. | Final trial number. | Relative number. |
|------------------------|------------------------|-----------------------|-----------------------|------------------------|------------------------|----------------------|--------------------|---------------------|----------------------|-----------------------------------|-----------------------|---------------------|---------------------|------------------|
| 56.17                  | 60.35                  | 57.66                 | 57.05                 | 66.99                  | 74.12                  | 70.29                | 68.50              | 72.47               | 71.25                |                                   |                       |                     |                     |                  |
| 63.0                   | 66.1                   | 65.7                  | 64.1                  | 72.4                   | 63.4                   | 57.6                 | 59.1               | 65.0                | 68.9                 |                                   |                       |                     |                     |                  |
| <i>s.</i>              | <i>s.</i>              | <i>s.</i>             | <i>s.</i>             | <i>s.</i>              | <i>s.</i>              | <i>s.</i>            | <i>s.</i>          | <i>s.</i>           | <i>s.</i>            | °                                 | <i>s.</i>             |                     |                     |                  |
| -1.369                 | -1.369                 | -1.324                | -1.150                | -1.157                 | -1.266                 | -1.297               | -1.467             | -1.496              | -1.620               | 66.17                             | - .00150              | 5.185               | 6.088               | 1                |
| -0.083                 | -0.476                 | -0.431                | -0.364                | -0.943                 | -1.087                 | -1.011               | -0.967             | -1.139              | -1.227               | 72.14                             | + .00091              | 3.574               | 6.363               | 2                |
| +0.524                 | +0.560                 | +0.569                | +0.279                | +0.343                 | +0.091                 | +0.203               | +0.319             | +0.183              | +0.094               | 64.93                             | + .00067              | 5.633               | 6.914               | 3                |
| +2.096                 | +1.917                 | +2.104                | +1.814                | +1.521                 | +1.270                 | +1.631               | +1.747             | +1.754              | +1.916               | 62.05                             | + .00099              | 5.705               | 7.385               | 4                |
| +0.774                 | +0.846                 | +1.104                | +0.850                | +0.414                 | +0.234                 | +0.274               | +0.211             | +0.183              | +0.059               | 94.72                             | + .00004              | 3.747               | 7.624               | 5                |
| -0.119                 | -0.369                 | -0.324                | -0.293                | -0.621                 | -0.623                 | -0.583               | -0.681             | -0.531              | -0.549               | 66.32                             | + .00213              | 8.350               | 8.870               | 6                |
| -0.690                 | -0.511                 | -0.431                | -0.436                | +0.057                 | +0.270                 | +0.274               | -0.039             | +0.254              | +0.273               | 86.20                             | + .00084              | 8.539               | 9.531               | 7                |
| +2.274                 | +2.024                 | +2.140                | +1.993                | +1.807                 | +1.484                 | +1.560               | +1.604             | +1.611              | +1.559               | 67.51                             | + .00208              | 8.483               | 10.609              | 8                |
| +1.060                 | +1.060                 | +0.926                | +0.743                | +0.771                 | +0.413                 | +0.310               | +0.176             | +0.040              | -0.477               | 93.35                             | + .00048              | 6.581               | 11.470              | 9                |
| -0.917                 | +0.917                 | +0.997                | +0.886                | +0.664                 | +0.234                 | +0.667               | +0.569             | +0.326              | +0.237               | 94.98                             | + .00064              | 10.399              | 11.481              | 10               |
| -2.583                 | -2.797                 | -2.467                | -2.436                | -3.129                 | -3.223                 | -3.261               | -3.146             | -3.460              | -3.549               | 75.09                             | + .00250              | 10.978              | 11.569              | 11               |
| +0.560                 | +0.381                 | +0.176                | +0.421                | -0.157                 | -0.409                 | -0.369               | -0.324             | -0.389              | -0.334               | 67.95                             | + .00280              | 10.321              | 12.346              | 12               |
| +2.203                 | +2.489                 | +2.283                | +2.136                | +2.593                 | +2.806                 | +2.596               | +2.426             | +2.861              | +2.630               | 83.97                             | + .00131              | 11.123              | 12.355              | 13               |
| +2.453                 | +2.239                 | +1.961                | +1.993                | +1.700                 | +1.377                 | +1.381               | +1.247             | +1.040              | +0.844               | 86.18                             | + .00012              | 8.231               | 12.755              | 14               |
| -0.976                 | -0.690                 | -0.681                | -0.650                | -0.729                 | -0.551                 | -0.571               | -0.610             | -0.689              | -0.763               | 76.24                             | + .00174              | 9.562               | 12.993              | 15               |
| -0.940                 | -1.011                 | -1.039                | -1.007                | -0.943                 | -0.944                 | -1.011               | -1.074             | -0.853              | -0.799               | 83.82                             | + .00068              | 12.090              | 13.035              | 16               |
| +1.703                 | +1.631                 | +1.747                | +1.707                | +1.271                 | +1.449                 | +1.489               | +1.426             | +1.290              | +1.166               | 64.84                             | + .00221              | 11.947              | 13.411              | 17               |
| -0.440                 | -0.690                 | -0.646                | -0.757                | -0.693                 | -0.730                 | -0.833               | -1.039             | -0.853              | -1.013               | 65.11                             | + .00111              | 12.886              | 13.711              | 18               |
| -1.690                 | -2.190                 | -1.967                | -2.043                | -2.550                 | -2.194                 | -1.904               | -1.717             | -1.889              | -1.977               | 37.98                             | + .00027              | 0.039               | 15.371              | 19               |
| -0.047                 | -0.190                 | -0.289                | -0.329                | -0.264                 | -0.016                 | -0.333               | -0.217             | -0.210              | -0.441               | 44.47                             | + .00090              | 13.435              | 15.412              | 20               |
| +0.096                 | -0.404                 | -0.503                | -0.471                | -1.157                 | -1.694                 | -1.690               | -1.646             | -1.746              | -1.727               | 73.39                             | + .00277              | 12.946              | 16.310              | 21               |
| +0.667                 | +0.167                 | +0.390                | +0.421                | -0.336                 | -0.516                 | -0.333               | -0.289             | -0.389              | -0.477               | 69.05                             | + .00379              | 15.465              | 16.910              | 22               |
| -0.524                 | -0.047                 | +0.211                | -0.007                | -1.086                 | -1.516                 | -1.083               | -1.039             | -1.139              | -1.191               | 112.07                            | + .00057              | 16.031              | 20.521              | 23               |
| +2.881                 | +1.987                 | +2.640                | +3.100                | +2.664                 | +2.806                 | +2.917               | +1.926             | +2.147              | +2.809               | 72.87                             | + .00130              | 11.419              | 21.191              | 24               |
| -2.739                 | +2.703                 | +2.283                | +2.207                | +2.557                 | +2.877                 | +2.631               | +2.461             | +2.647              | +2.487               | 76.86                             | + .00158              | 20.123              | 22.226              | 25               |
| -0.810                 | -0.917                 | +1.247                | +1.350                | +0.843                 | +0.841                 | +0.881               | +0.890             | +0.861              | +0.809               | 67.27                             | + .00383              | 20.803              | 22.817              | 26               |
| -0.667                 | -0.631                 | +0.890                | +0.957                | +0.629                 | +0.913                 | +1.024               | +1.247             | +1.111              | +0.987               | 67.65                             | + .00320              | 21.626              | 23.755              | 27               |
| -0.047                 | -0.190                 | -0.217                | -0.257                | -0.229                 | +0.020                 | -0.369               | -0.467             | -0.317              | -0.477               | 53.61                             | + .00224              | 23.165              | 26.532              | 28               |
| +1.739                 | +1.739                 | +1.604                | +1.493                | +1.307                 | +1.127                 | +1.167               | +1.211             | +1.147              | +1.201               | 72.46                             | + .00091              | 27.849              | 30.013              | 29               |
| +0.846                 | +0.881                 | +1.104                | +1.529                | +0.700                 | +0.056                 | +0.239               | +0.247             | -0.317              | -0.477               | 30.53                             | + .00031              | 21.483              | 30.537              | 30               |
| +0.739                 | -0.096                 | -0.181                | -0.400                | -0.764                 | -1.373                 | -1.583               | -1.824             | -1.996              | -1.977               | 64.12                             | + .00118              | 14.886              | 31.943              | 31               |
| +1.917                 | +2.167                 | +2.319                | +2.243                | +2.771                 | +3.484                 | +3.703               | +3.854             | +4.040              | +4.201               | 75.77                             | + .00230              | 25.572              | 32.573              | 32               |
| +0.953                 | +0.739                 | +1.176                | +1.350                | +0.129                 | -0.266                 | +0.024               | +0.069             | -0.031              | +0.094               | 73.98                             | + .00356              | 31.068              | 33.448              | 33               |
| +1.596                 | +1.703                 | +1.676                | +1.636                | +1.593                 | +1.449                 | +1.596               | +1.604             | +1.504              | +1.487               | 65.06                             | + .00064              | 35.867              | 36.305              | 34               |
| -0.654                 | -1.119                 | -1.289                | -1.864                | -1.050                 | -1.194                 | -1.297               | -1.289             | -1.281              | -1.299               | 81.18                             | + .00238              | 35.207              | 42.698              | 35               |
| +2.417                 | +2.060                 | +2.283                | +2.279                | +1.414                 | +1.306                 | +1.274               | +1.319             | +1.183              | +1.130               | 73.87                             | + .00150              | 40.757              | 44.258              | 36               |
| +2.060                 | +1.810                 | +1.283                | +1.279                | +1.236                 | +0.591                 | +0.310               | -0.181             | -0.076              | +0.309               | 68.13                             | + .00197              | 32.817              | 44.262              | 37               |
| +1.631                 | +1.024                 | +0.711                | +0.493                | +0.486                 | +1.341                 | +1.631               | +1.354             | +1.397              | +1.523               | 61.22                             | + .00174              | 35.369              | 46.861              | 38               |
| -0.690                 | -0.547                 | -0.539                | -0.936                | -0.229                 | +0.091                 | -0.047               | -0.396             | -0.710              | -0.334               | 72.04                             | + .00420              | 75.646              | 79.132              | 39               |
| -0.119                 | -0.154                 | -0.146                | -0.221                | -0.371                 | -0.480                 | -0.476               | -0.574             | -0.674              | -0.763               | 1300.04                           | + .000008             | 78.678              | 81.334              | 40               |
| -1.226                 | -1.511                 | -2.074                | -3.543                | -1.586                 | -2.801                 | -3.511               | -3.289             | -3.210              | -3.441               | 43.12                             | + .00137              | 81.167              | 136.075             | 41               |

*g* Heinrich auxiliary self-adjusting balance; Giles non-magnetic shield.

*h* Ordinary balance, palladium spring.

*i* Paillard's non-magnetic balance, palladium spring.

*j* Ordinary balance, white steel spring.

*k* Plain compensation balance, palladium spring.

*l* Heinrich regulator, palladium spring.



*nometers, November 1, 1890, to March 4, 1891.*

ember 31; after that in chronometer room.]

[illegible]

*chronometers January 1 to May 23, 1891.*

March 14; after that in chronometer room.]

| Mar. 21 to<br>Mar. 28. | Mar. 28 to<br>Apr. 4. | Apr. 4 to<br>Apr. 11. | Apr. 11 to<br>Apr. 18. | Apr. 18 to<br>Apr. 25. | Apr. 25 to<br>May 2. | May 2 to<br>May 9. | May 9 to<br>May 16. | May 16 to<br>May 23. | Temperature of compen-<br>sation. | Temperature-constant. | First trial number. | Final trial number. | Relative number. |
|------------------------|-----------------------|-----------------------|------------------------|------------------------|----------------------|--------------------|---------------------|----------------------|-----------------------------------|-----------------------|---------------------|---------------------|------------------|
| 60° 35                 | 57° 66                | 57° 05                | 66° 99                 | 74° 12                 | 70° 23               | 68° 50             | 72° 47              | 71° 28               |                                   |                       |                     |                     |                  |
| 66.1                   | 65.6                  | 64.1                  | 72.4                   | 63.4                   | 57.6                 | 59.1               | 65.0                | 68.9                 | Temperature of compen-<br>sation. | Temperature-constant. | First trial number. | Final trial number. | Relative number. |
| <i>g.</i>              | <i>g.</i>             | <i>g.</i>             | <i>g.</i>              | <i>h.</i>              | <i>g.</i>            | <i>g.</i>          | <i>g.</i>           | <i>g.</i>            | <i>g.</i>                         | <i>g.</i>             |                     |                     |                  |
| +0.667                 | +0.961                | +0.921                | +0.629                 | +0.484                 | +0.239               | +0.390             | +0.397              | +0.380               | 67.23                             | +0.00197              | 8.553               | 9.578               | 1                |
| −0.047                 | +0.069                | +0.171                | −0.371                 | −0.337                 | −0.440               | −0.396             | −0.389              | −0.477               | 68.90                             | +0.00304              | 10.740              | 10.976              | 2                |
| −0.667                 | +0.676                | +0.779                | +0.486                 | +1.091                 | +0.881               | +0.640             | +0.826              | −0.666               | 62.96                             | +0.00213              | 13.367              | 14.599              | 3                |
| −0.511                 | −0.253                | −0.150                | −0.336                 | −0.230                 | −0.404               | −0.396             | −0.103              | −0.191               | 65.39                             | +0.00343              | 16.941              | 17.929              | 4                |
| +1.703                 | +1.819                | +1.743                | +1.379                 | +0.877                 | +1.131               | +1.069             | +0.861              | −0.916               | 80.70                             | +0.00182              | 19.248              | 20.136              | 5                |
| −0.619                 | −0.610                | −0.721                | −1.264                 | +0.873                 | −0.976               | −1.039             | −0.996              | −0.977               | 64.87                             | +0.00240              | 22.930              | 25.050              | 6                |
| +0.667                 | +0.854                | +1.064                | −0.086                 | −0.587                 | −0.226               | −0.074             | −0.174              | −0.191               | 73.16                             | +0.00411              | 23.336              | 25.108              | 7                |
| +0.953                 | +0.854                | +0.886                | +0.986                 | +1.020                 | +0.917               | +1.247             | +0.611              | −0.013               | 51.06                             | +0.00111              | 19.237              | 30.154              | 8                |
| −0.047                 | −0.324                | −0.364                | −0.479                 | +0.056                 | −0.511               | −0.324             | −0.067              | −0.013               | 66.33                             | +0.00197              | 44.609              | 48.404              | 9                |
| −3.690                 | −3.681                | −3.614                | −3.800                 | −3.837                 | −4.511               | −4.396             | −4.281              | −4.299               | 62.75                             | +0.00386              | 64.127              | 68.437              | 10               |
| +0.953                 | +0.819                | +0.921                | +0.986                 | +0.841                 | +0.846               | +0.711             | +0.719              | +0.701               |                                   | Indeterminate.        |                     |                     | 11               |











